ISSN- O: 2458 - 868X, ISSN–P: 2458 – 8687
National Library of Medicine - ID: 101731606

International Journal of Medical Science and Innovative Research (IJMSIR)
IJMSIR : A Medical Publication Hub
Available Online at: www.ijmsir.com
Volume – 11, Issue – 3, June – 2026, Page No. : 164 – 172

A Comparative Analysis of Antimicrobial Resistance Patterns in Klebsiella species: Intensive Care versus Non-Intensive Care Isolates in a Maternal-Pediatric Tertiary Center of Semi-Arid Zone in Western Rajasthan, India

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Citation this Article: Dr. Jayant Ramawat, Dr. R.S. Parihar, Dr. Mukesh Sharma, Dr. Priyanka Choudhary, Dr. Sakshi Jain, Dr. Divya Aggarwal, "A Comparative Analysis of Antimicrobial Resistance Patterns in Klebsiella species: Intensive Care versus Non-Intensive Care Isolates in a Maternal-Pediatric Tertiary Center of Semi-Arid Zone in Western Rajasthan, India", IJMSIR – June – 2026, Vol – 11, Issue – 3, P. No. 164 – 172.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Background: Antimicrobial resistance (AMR) in Klebsiella species is an increasing challenge in maternal and pediatric healthcare, particularly in intensive care settings where multidrug-resistant (MDR) infections are common.

Objective: To compare antimicrobial resistance patterns of Klebsiella isolates obtained from ICU and non-ICU settings in a tertiary maternal-pediatric care center.

Methods: This retrospective cross-sectional study analyzed 60 non-duplicate Klebsiella isolates collected between February and April 2026 at Maternal-Paediatric Tertiary Center. Isolates were categorized into ICU (NICU/PICU) and non-ICU groups. Antimicrobial susceptibility testing was performed according to CLSI 2024 guidelines, and resistance patterns were statistically compared using Fisher's exact test.

Results: Pediatric patients constituted 63.3% of cases, while adult maternity patients accounted for 36.6%. Urine was the most common specimen (58.3%), followed by stool and endotracheal tips. Overall resistance was high for levofloxacin (68.3%), ceftazidime (66.6%), cefepime (66.6%), and gentamicin (66.6%). Meropenem resistance was observed in 25% of isolates. ICU isolates showed significantly higher resistance to ceftazidime and gentamicin, with 100% resistance compared to 60.7% in non-ICU isolates (p=0.038). Carbapenem resistance was also higher in ICU isolates (33.3% vs. 23.5%). In contrast, nitrofurantoin and fosfomycin retained excellent activity against urinary isolates.

Conclusion: ICU-derived Klebsiella isolates demonstrated more aggressive MDR patterns than non-ICU isolates, highlighting the need for strict infection control and antimicrobial stewardship. Nitrofurantoin and

fosfomycin remain effective therapeutic options for urinary tract infections in maternal and pediatric patients.

Keywords: Klebsiella Pneumoniae, Antimicrobial Resistance, Multidrug Resistance, ESBL, Carbapenem Resistance, NICU, PICU, Maternal Health, Pediatric Infections, Urinary Tract Infection, Antimicrobial Stewardship.

Introduction

Antimicrobial resistance (AMR) has become a major global health challenge, significantly limiting the effectiveness of modern antibiotics. Among Gram-negative pathogens, Klebsiella pneumoniae is a leading cause of community- and hospital-acquired infections due to its remarkable ability to acquire multidrug resistance mechanisms.[1,5]

The burden of Klebsiella infections is especially high in maternal and pediatric healthcare settings. In NICU and PICU environments, Klebsiella is commonly associated with severe device-related infections such as neonatal sepsis and ventilator-associated pneumonia, often involving multidrug-resistant (MDR) strains resistant to standard empiric therapies[2,3,6]. In non-ICU settings, Klebsiella frequently causes urinary tract infections (UTIs) in children and pregnant women, increasingly complicated by ESBL- and carbapenemase-producing isolates[13-17]. Maternal gastrointestinal and vaginal colonization may also contribute to neonatal transmission[9,10].

Despite the clinical significance of these infections, limited data exist regarding differences in antimicrobial resistance between ICU and non-ICU settings within combined maternal-pediatric centers. This study aimed to analyze the demographic profile, specimen distribution, and antimicrobial susceptibility patterns of Klebsiella isolates, while comparing resistance profiles between ICU and non-ICU isolates to support targeted antimicrobial stewardship and infection control practices.

Aim and Objectives

Aim

To evaluate the antimicrobial susceptibility patterns of Klebsiella species in a maternal and pediatric tertiary care center.

Objectives

1. To assess the distribution of Klebsiella isolates by age, gender, and specimen type.
2. To determine susceptibility and resistance patterns against commonly used antibiotics.
3. To compare antimicrobial resistance profiles between ICU (NICU/PICU) and non-ICU isolates.

Methodology

A retrospective cross-sectional study was conducted at a tertiary maternal and pediatric care center from February to April 2026. All non-duplicate Klebsiella isolates recovered from clinical specimens were included. Demographic details, specimen type, and hospital location were recorded.

Patients were categorized into pediatric (≤18 years) and adult maternal cohorts. Specimens included urine, endotracheal tips, stool, pus, vaginal swabs, sputum, and throat swabs. Isolates were further classified into ICU (NICU/PICU) and non-ICU groups.

Bacterial identification and antimicrobial susceptibility testing were performed using standard microbiological methods according to CLSI 2024 guidelines. Antibiotics tested included cephalosporins, carbapenems, aminoglycosides, fluoroquinolones, and urinary-specific agents such as nitrofurantoin and fosfomycin.

Multidrug resistance (MDR), ESBL production, and carbapenem resistance were interpreted using standard criteria. Descriptive statistics and Fisher's exact test were

used for analysis, with $p<0.05$ considered statistically significant.

Results

A total of 60 non-duplicate Klebsiella isolates were included in this retrospective analysis. The cohort demonstrated a bimodal age distribution characteristic of a combined maternal-pediatric center. Pediatric patients (aged ≤18 years) accounted for 63.3% (n=38) of the isolates, with a significant proportion being neonates and infants under one year of age. Adult patients (aged >18 years) accounted for 36.6% (n=22) of the isolates, all of whom were female, representing the obstetrics and gynecology maternity population. Overall, females comprised 66.6% (n=40) of the total study population.

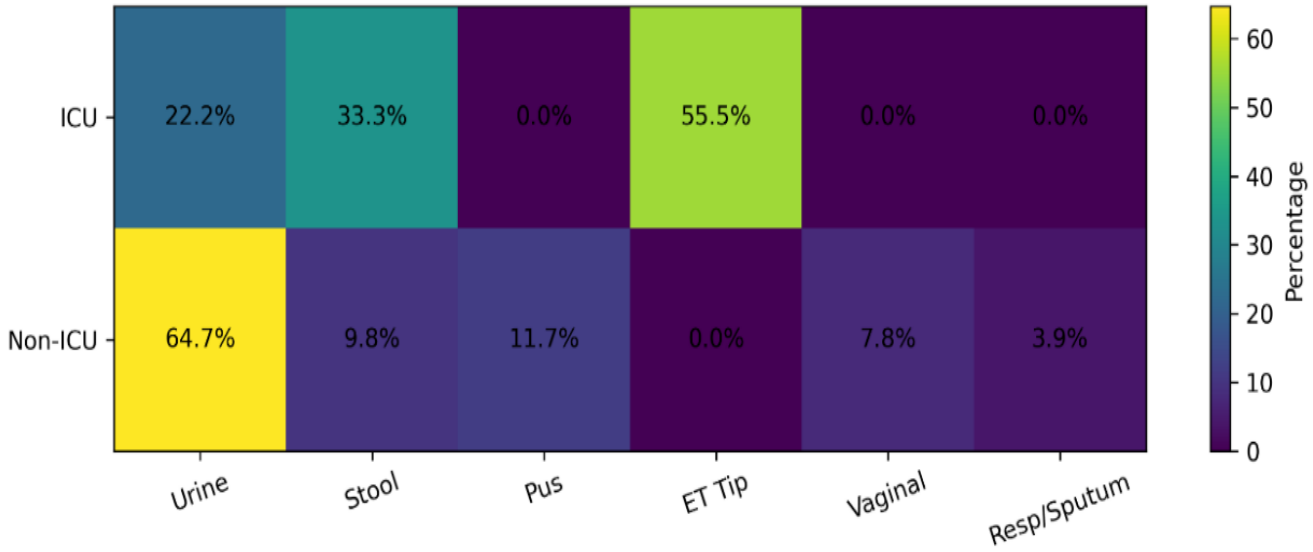
Urine was the most frequently isolated clinical specimen, accounting for 58.3% (n=35) of all cultures, followed by Stool (13.3%, n=8), Pus/Wound swabs (10.0%, n=6), and Endotracheal (ET) Tips (8.3%, n=5). Vaginal Swabs, Throat Swabs, and Sputum comprised the remainder.

When stratified by hospital location, 15.0% (n=9) of the isolates originated from Intensive Care Units (NICU/PICU), while the vast majority (85.0%, n=51) originated from Non-ICU settings (general pediatric wards, maternity wards, and outpatient clinics). A distinct correlation between specimen type and hospital unit was observed: all device-associated ET Tip isolates (100%, n=5) originated exclusively from the ICU cohort. Conversely, all Vaginal Swab isolates (n=4) and the majority of Urine isolates (94.2%, n=33/35) originated from the Non-ICU cohort (Fig 1).

Table 1: Baseline Demographics and Specimen Distribution

Characteristic	Total Cohort (N=60)	ICU Cohort (n=9)	Non-ICU Cohort (n=51)
Gender, n (%)			
Female	40 (66.6%)	2 (22.2%)	38 (74.5%)
Male	20 (33.3%)	7 (77.7%)	13 (25.5%)
Age Category, n (%)			
Pediatric (≤18 years)	38 (63.3%)	9 (100%)	29 (56.8%)
Adult (>18 years)	22 (36.6%)	0 (0%)	22 (43.1%)
Specimen Type, n (%)			
Urine	35 (58.3%)	2 (22.2%)	33 (64.7%)
Stool	8 (13.3%)	3 (33.3%)	5 (9.8%)
Pus	6 (10.0%)	0 (0%)	6 (11.7%)
Endotracheal (ET) Tip	5 (8.3%)	5 (55.5%)	0 (0%)
Vaginal Swab	4 (6.6%)	0 (0%)	4 (7.8%)
Respiratory Swab / Sputum	2 (3.3%)	0 (0%)	2 (3.9%)

Figure 1. Specimen Distribution Across Hospital Units



The overall Klebsiella cohort exhibited high rates of multidrug resistance, particularly concerning extended-spectrum beta-lactamase (ESBL) production. Resistance to third- and fourth-generation cephalosporins, a proxy for the ESBL phenotype, was prevalent; 66.6% (n=40) of all isolates were resistant to Ceftazidime (CAZ) and Cefepime (CPM). High resistance was also observed for Gentamicin (66.6%, n=40) and Levofloxacin (68.3%, n=41). Carbapenem resistance, indicative of Carbapenem-Resistant Enterobacteriaceae (CRE), was lower but clinically significant, with 25.0% (n=15) of the total isolates demonstrating resistance to Meropenem (MRP). Notably, among drugs specifically targeted for lower urinary tract infections, susceptibility remained robust. Of the isolates tested against Nitrofurantoin (NIT) and Fosfomycin (FO) (primarily urine and vaginal specimens), resistance was negligible, with 100% susceptibility noted in the recorded Nitrofurantoin data and >90% susceptibility to Fosfomycin.

NICU/PICU versus Non-ICU Isolates comparative analysis revealed distinct, aggressive resistance profiles in the ICU cohort compared to the Non-ICU cohort. Isolates originating from the NICU/PICU—dominated by pediatric patients and ET Tip specimens—demonstrated universal resistance (100%) to Ceftazidime and Gentamicin, compared to 60.7% resistance in the Non-ICU setting.

Furthermore, Meropenem resistance was higher in the intensive care setting, with 33.3% of ICU isolates testing resistant, compared to 23.5% of Non-ICU isolates. While the Non-ICU isolates (largely maternal UTIs) showed considerable resistance to cephalosporins and fluoroquinolones, they retained broader susceptibility to carbapenems and aminoglycosides compared to the device-associated ICU strains (Fig 2).

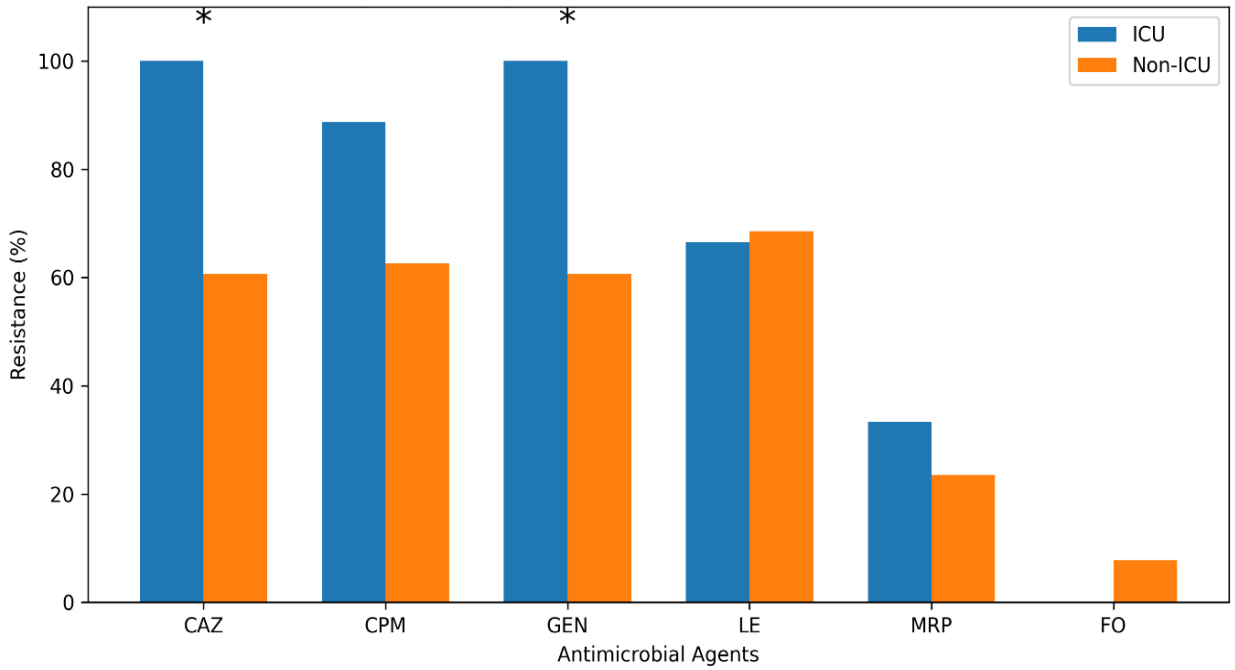
Table 2: Comparative Antimicrobial Resistance Profile (ICU vs. Non-ICU)

Antimicrobial Agent	Class	Total Cohort Resistance %	ICU Cohort Resistance (n=9)	Non-ICU Cohort Resistance (n=51)	p-value	Significance
Ceftazidime (CAZ)	3rd Gen Cephalosporin	66.6% (40/60)	100% (9/9)	60.7% (31/51)	0.038	Significant
Cefepime (CPM)	4th Gen Cephalosporin	66.6% (40/60)	88.8% (8/9)*	62.7% (32/51)	0.231	NS
Gentamicin (GEN)	Aminoglycoside	66.6% (40/60)	100% (9/9)	60.7% (31/51)	0.038	Significant
Levofloxacin (LE)	Fluoroquinolone	68.3% (41/60)	66.6% (6/9)	68.6% (35/51)	1.000	NS
Meropenem (MRP)	Carbapenem	25.0% (15/60)	33.3% (3/9)	23.5% (12/51)	0.648	NS
Fosfomycin (FO)	Phosphonic Acid	6.6% (4/60)	0% (0/9)*	7.8% (4/51)	1.000	NS
Nitrofurantoin (NIT)	Nitrofuran	0%	N/A (Not tested)	0%	N/A	N/A

Note: NS = Not Statistically Significant, N/A = Not Available.

Fisher's Exact Test performed.

Figure 2. Comparative Antimicrobial Resistance Profile



Discussion

The present study highlights a substantial burden of multidrug-resistant (MDR) Klebsiella species within our tertiary maternal and pediatric care center, revealing distinctly divergent antimicrobial resistance profiles between intensive care (ICU) and non-intensive care (Non-ICU) settings. Overall, we observed alarming rates of resistance to extended-spectrum cephalosporins (66.6% for ceftazidime and cefepime) and aminoglycosides (66.6% for gentamicin), indicating a high prevalence of Extended-Spectrum Beta-Lactamase (ESBL) producing isolates. These findings align with the growing global consensus that Klebsiella pneumoniae has become a dominant nosocomial pathogen, rapidly accumulating resistance mechanisms that complicate empiric therapy in vulnerable maternal and pediatric populations[1].

The most critical finding in our cohort was the aggressive resistance profile of isolates originating from the NICU and PICU. In these critical care settings—dominated by pediatric patients and device-associated specimens such as endotracheal (ET) tips—we observed 100% resistance to both ceftazidime and gentamicin. This renders the World Health Organization's (WHO) standard empiric first-line regimen (ampicillin and gentamicin) completely ineffective for neonatal sepsis in our unit. This catastrophic loss of first-line efficacy is increasingly reported in low- and middle-income countries and sub-Saharan Africa, where high mortality rates are strongly linked to empiric treatment failure in Gram-negative neonatal sepsis[2-4].

Furthermore, carbapenem resistance (measured via meropenem) was notably higher in the ICU cohort (33.3%) compared to the Non-ICU cohort (23.5%). The emergence of Carbapenem-Resistant Klebsiella pneumoniae (CRKP) in neonatal units is a severe global health threat. Outbreaks of CRKP in NICUs, often driven by the clonal horizontal transmission of genes such as blaNDM-1, are highly associated with invasive devices (like the ET tips frequent in our data), prolonged parenteral nutrition, and significant infant mortality[5-7]. The distinct ecological pressure of the ICU, characterized by heavy broad-spectrum antibiotic use, necessitates rigorous, targeted infection control measures, including strict hand hygiene and active surveillance, to prevent the clonal spread of these devastating pathogens[8].

In contrast to the device-associated respiratory isolates of the ICU, the Non-ICU cohort was primarily driven by urinary and mucosal tract isolates (vaginal swabs) from adult maternity patients and older pediatric ward patients. The identification of highly resistant Klebsiella in maternal vaginal swabs and stool samples underscores a critical transmission pathway. Recent genomic and epidemiological tracking in maternity wards has demonstrated that the maternal gastrointestinal and vaginal tracts serve as significant reservoirs for ESBL-producing Enterobacteriaceae[9-10].

During delivery, neonates are frequently colonized by these maternal multidrug-resistant microflora[9]. Once gut colonization is established in the neonate, it serves as a direct conduit to invasive extraintestinal infections, including late-onset sepsis[11-12]. Therefore, the high resistance rates seen in our maternal cohort directly threaten neonatal outcomes, blurring the lines between adult and pediatric infection control protocols within a combined hospital setting.

Urine was the predominant specimen in our overall cohort (58.3%), reflecting the high burden of UTIs in both pregnant women and pediatric patients[13-14]. While the Non-ICU urine isolates exhibited high resistance to cephalosporins (60.7% for ceftazidime) and fluoroquinolones (68.6% for levofloxacin), they retained

broad susceptibility to older, urinary-specific agents. Remarkably, 100% of tested isolates were susceptible to nitrofurantoin, and over 90% were susceptible to fosfomycin.

This presents a vital clinical opportunity. The rising threat of ESBL-producing uropathogens in children and pregnant women severely limits the availability of safe, oral empiric therapies[13,15]. Our data strongly supports the repositioning of fosfomycin and nitrofurantoin as first-line empiric treatments for uncomplicated Klebsiella UTIs in our maternity and pediatric wards, sparing carbapenems for life-threatening systemic infections.

Our study demonstrates that isolates originating from the NICU/PICU exhibit a statistically significant increase in resistance to third-generation cephalosporins and aminoglycosides ($p = 0.038$) compared to non-ICU ward isolates. This provides quantitative evidence that the ICU environment acts as a specific reservoir for highly resistant Gram-negative pathogens, likely necessitating more aggressive empirical therapy adjustments than those required for ward-based infections.

Finally, it is crucial to recognize that the boundary between the ICU and the community is porous. Infants who acquire CRKP or ESBL gut colonization during a prolonged NICU stay can present weeks or months later to the pediatric emergency department or outpatient clinics with severe, community-onset multidrug-resistant UTIs[16]. This phenomenon likely explains a portion of the highly resistant pediatric urine isolates seen in our Non-ICU cohort, emphasizing the need for meticulous clinical histories regarding prior NICU admissions[16-17].

Limitations

This study has several limitations. Its retrospective nature precludes the assessment of longitudinal clinical outcomes such as infection-attributable mortality or exact duration of hospital stay prior to infection. Additionally, the lack of molecular genotyping limits our ability to definitively prove clonal outbreaks within the facility, relying instead on broad phenotypic resistance patterns as epidemiological proxies[18].

Conclusion

In conclusion, Klebsiella exhibits highly distinct clinical manifestations depending on the hospital microenvironment. In the intensive care setting, it acts as an opportunistic, highly resistant respiratory pathogen capable of thwarting standard empiric sepsis therapies. On the maternity and pediatric wards, it is a primary driver of complicated UTIs and maternal-neonatal colonization. Addressing this dual threat requires a bifurcated approach: intense antimicrobial stewardship to preserve carbapenems in the NICU, alongside the utilization of effective, older oral agents like nitrofurantoin forward-based urinary infections.

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